NRG Rocket Capstone Team

Bob Nimcheski - Financial Manager & Budget Liason
Emanuel Salinas - Project Manager
Lee Freytes Colón - Logistics Manager
Thomas Sasser - CAD Engineer
Adriana Fisk - Test Engineer
Stonn Billy - Manufacturing Engineer

NORTHERN ARIZONA UNIVERSITY

Project Description

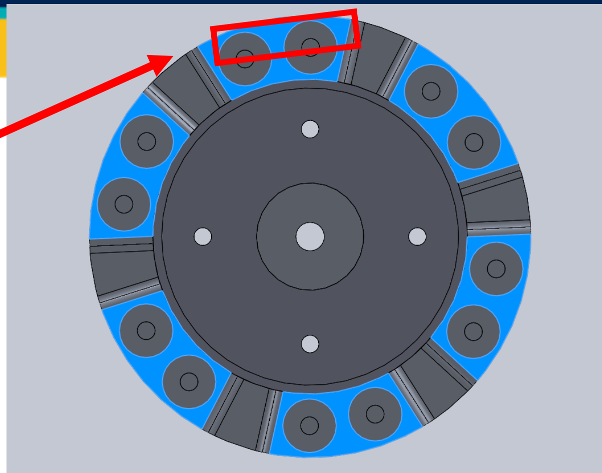
Design, manufacture, integrate, and test a magnetic separation system

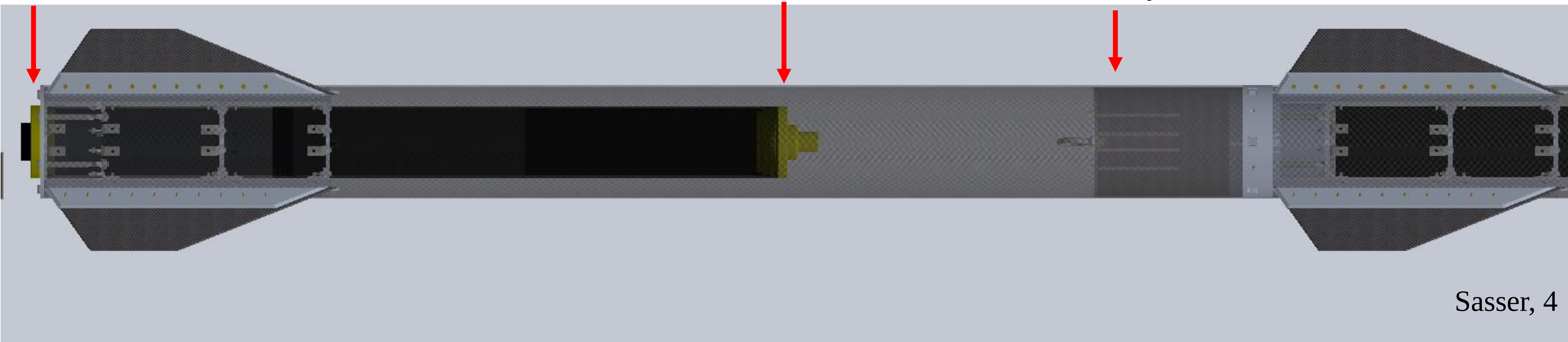
- System shall provide adequate force to separate the two-stage vehicle
- System should be able to be safely released to mimic integration or maintenance activities
- Ground testing shall be performed to demonstrate that the system meets all requirements
- Final product will include design and analysis in a final report
- Rocket will be analyzed to ensure safe flights
- Rocket will be designed to ensure multiple flights are possible with minimal maintenance

Main Rocket Systems

- The presentation will cover the following systems:
  - **Structural Design**
  - **Recovery Design**
  - **Separation Techniques**
  - **Flight Simulation Predictions**
  - **Future Testing**
  - **Future Work**

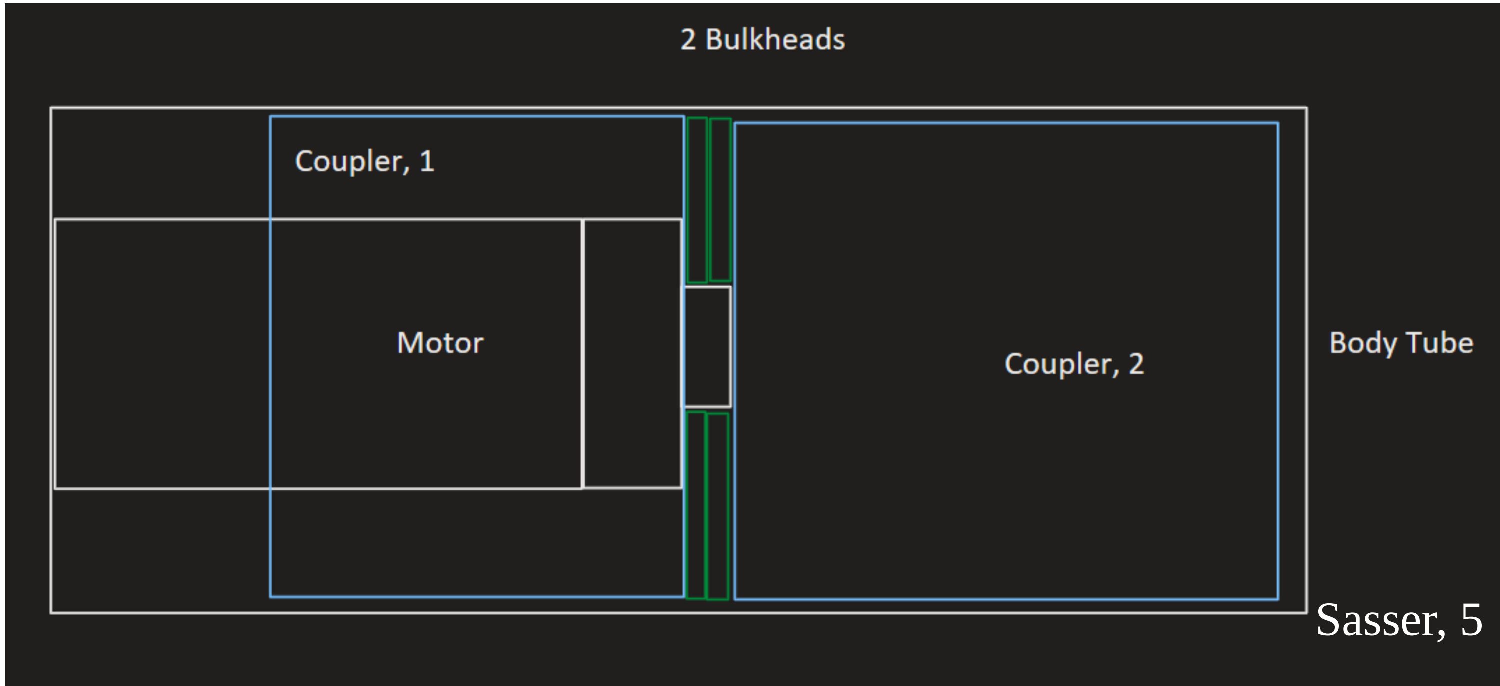
Main Structural Systems





Forward Motor Retainer

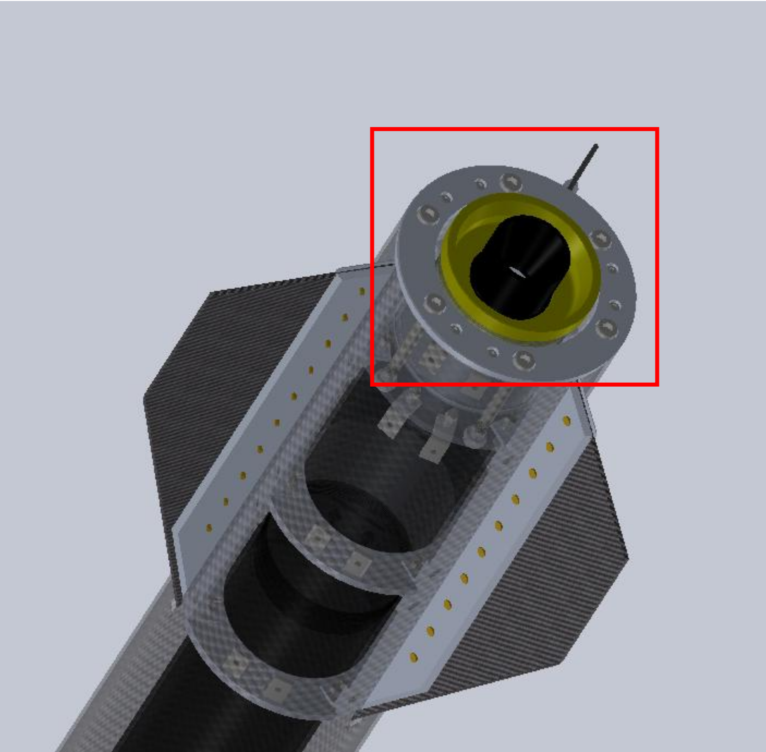
- The **Forward Motor Retainer** will be constructed with:
  - **Two Couplers**
  - **Two Bulkheads**
  - **Epoxy**
- The **Couplers** will closely match the inner diameter of the **Body Tube**
  - Additionally, they will be epoxied to the body tube
  - **Couplers** will be made of **Fiber Glass**
- The **Bulkheads** will be placed against the **Forward Side** of the **Motor Casing**
  - The **Bulkheads** will also be epoxied to the **Couplers**
  - **Bulkheads** will be made of **Carbon Fiber**



Aft Motor Retainer

- The **Aft Motor Retainer** will thread into the **Motor Casing**.
  - Additionally, it will be **Welded** to the **Aft Centering Ring**.
  - This can be seen in the red square.

- Both **Forward** and **Aft Motor Retainers** will provide **Reaction Forces** and distribute the **Motor Impulse Force.**

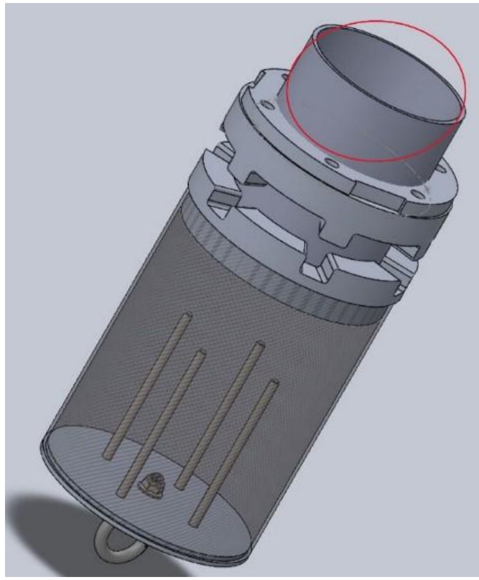


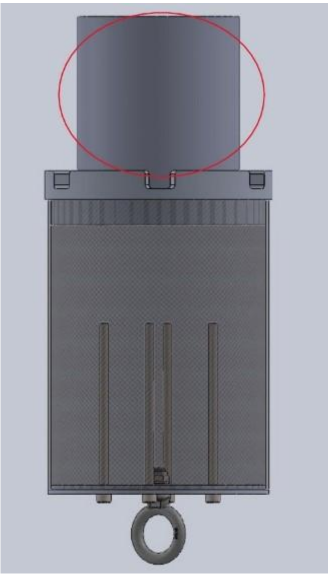
Coupler

Coupler

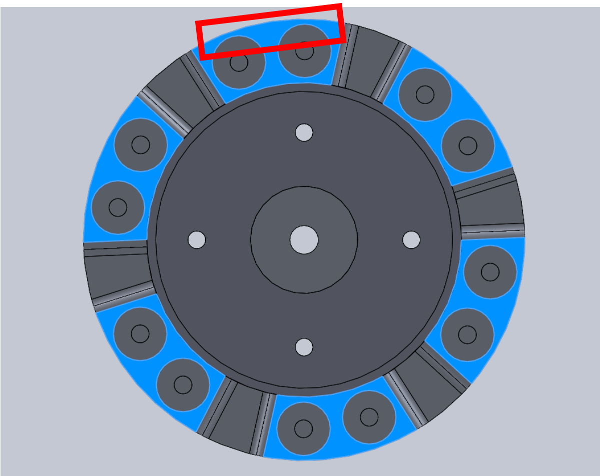
Predicted Weak Points

- Location of concern within separation system due to thin wall
- This will be the weakest point of the rocket
- MATLAB function was created to solve critical buckling load





- Another location of concern also within separation system due to thin wall
- This will be the 2nd weakest point on the rocket due to thinness of wall
- MATLAB function also helped solve critical buckling load



Main Recovery Systems

- The **Main Recovery Systems** include:
  - **Avionics Bay**
  - **Recovery Bay**

- The **Avionics Bay** will contain the **Flight Computers** and other electronics.
  - The **Flight Computers** control the **Recovery Systems**.
  - The additional electronics will control the **MAG-SEP System.**

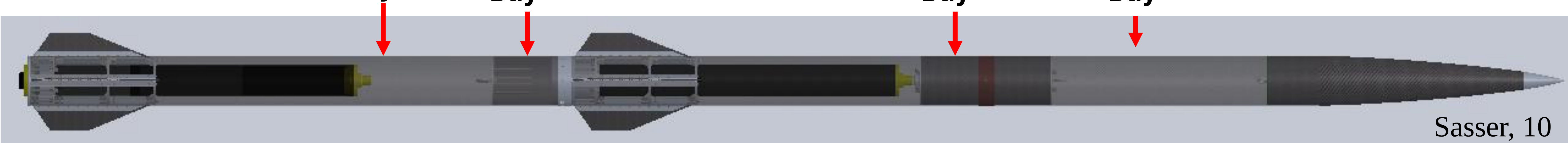
- The **Recovery Bay** will contain the **Parachutes** and **Black Powder Charges.**

Booster Recovery Bay

Booster Avionics Bay

Sustainer Avionics Bay

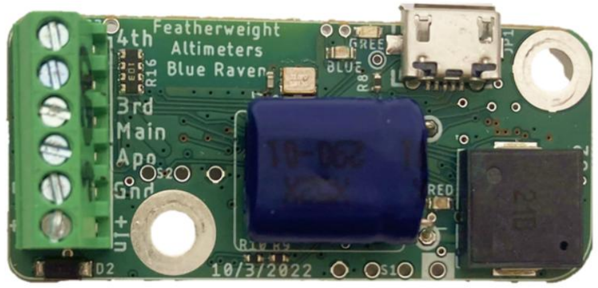
Sustainer Recovery Bay



Rocket Avionics

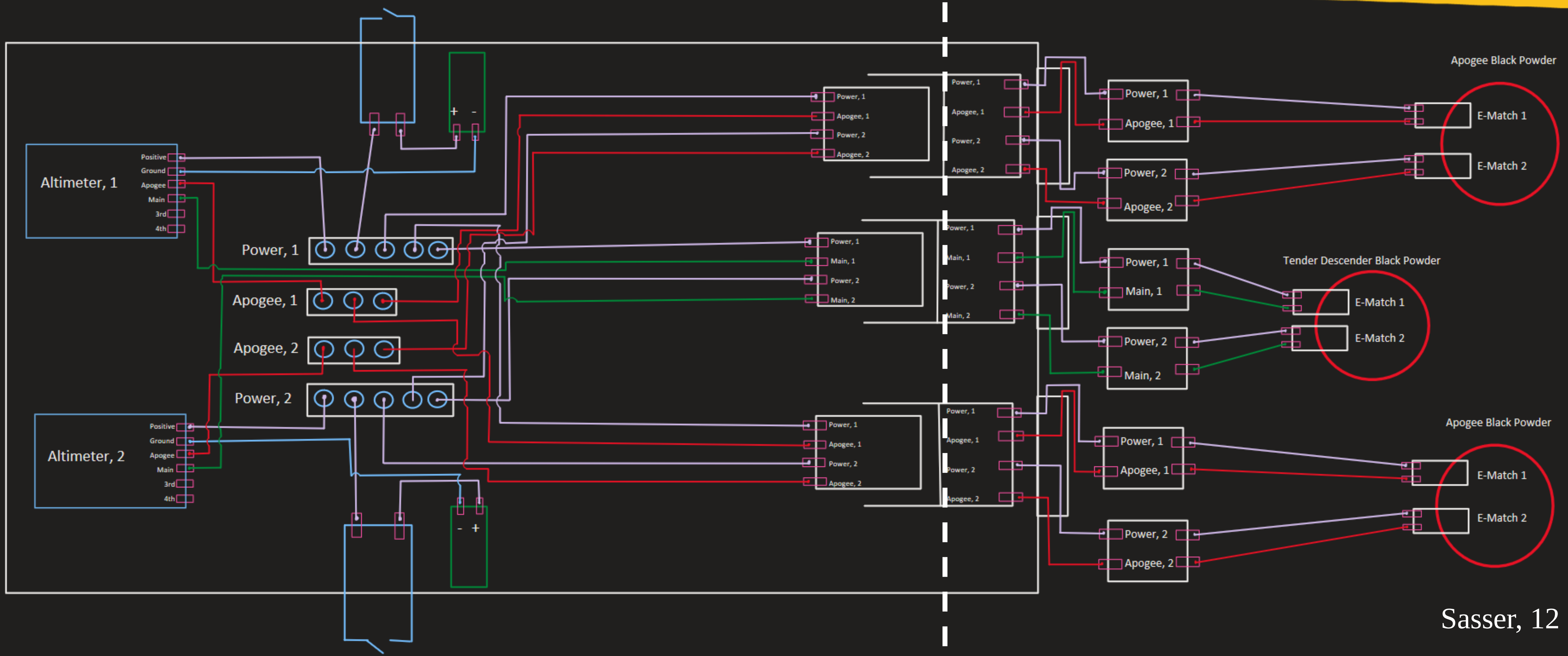
- Each **Avionics Bay** will be equipped with two **Altimeters** and one **GPS**.
- The **Altimeters** will record data and **Ignite Black Powder Charges** at specific stages in the flight.
- The altimeters can be programmed via a phone application.
- The **GPS** will record the position.
- The purpose of **Two Altimeters** is **Redundancy**, incase one fails.

Blue Raven Altimeter

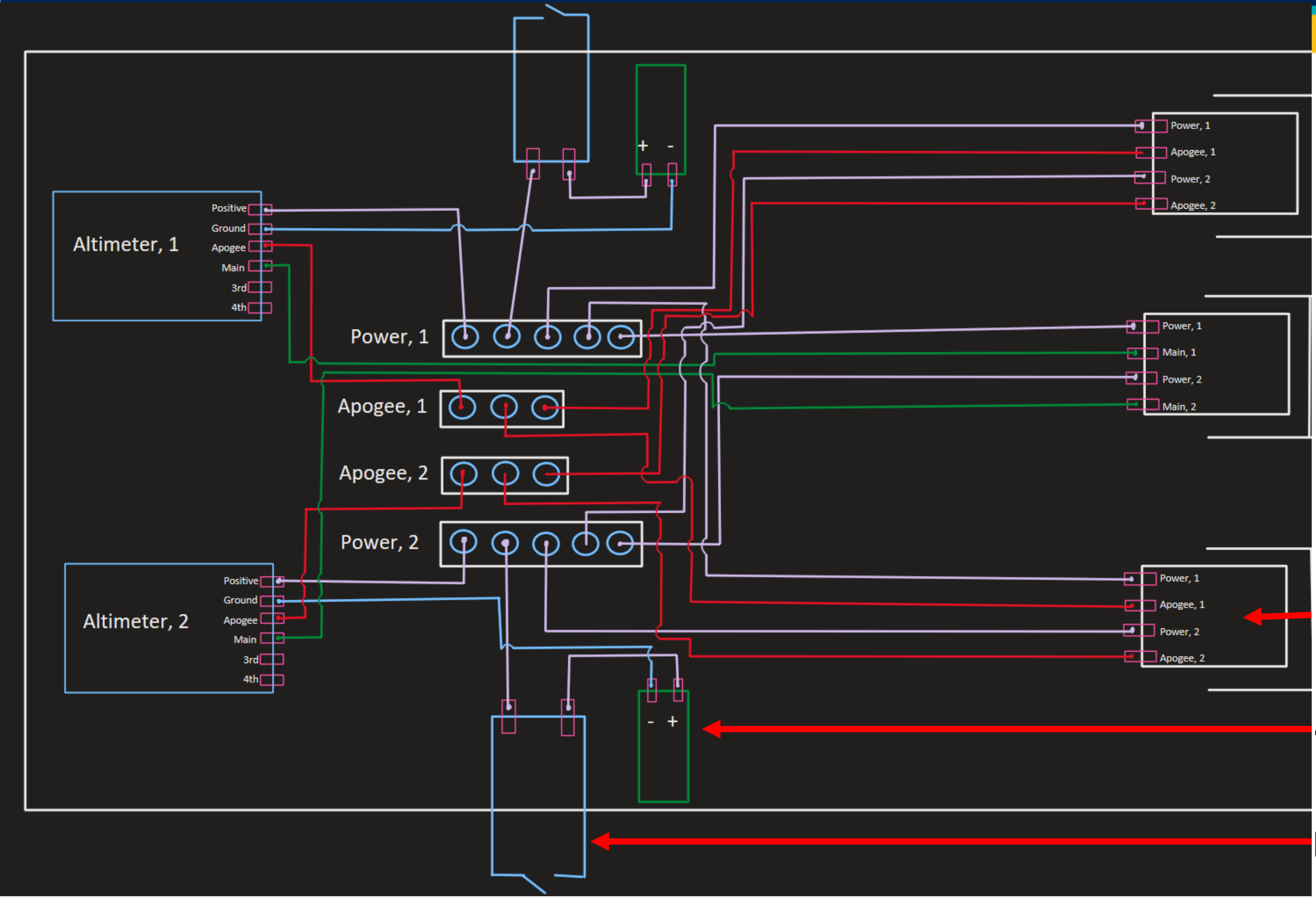


Featherweight GPS

Avionics Wiring Diagram



Avionics Wiring Diagram (Inside Coupler)



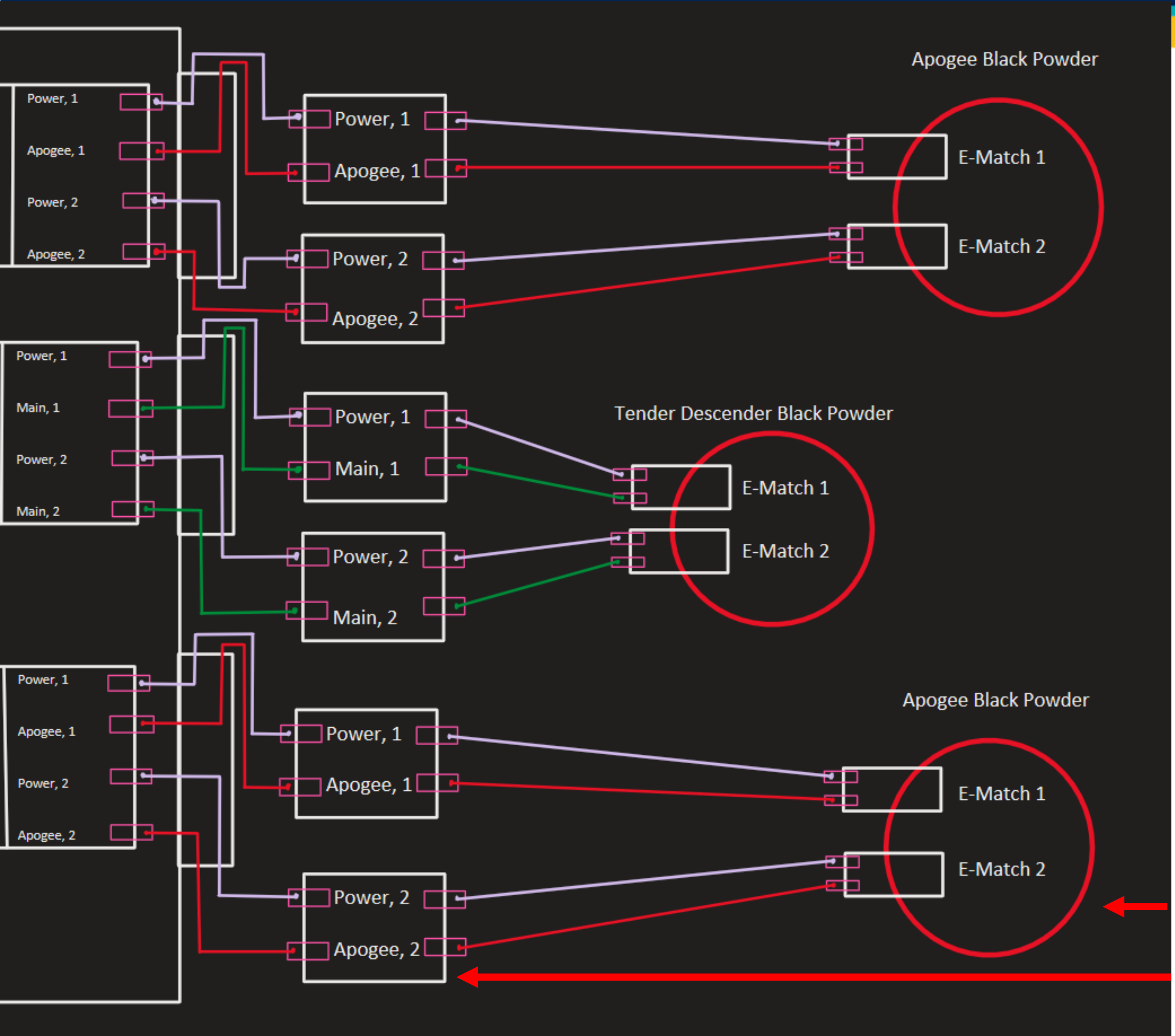
- Each altimeter will have two bread boards, a key switch, and battery.
- These key switches will activate the altimeters.
- The bread boards will increase the number of outputs for positive and apogee.

Quick Connect

12V Battery

Key Switch

Avionics Wiring Diagram (Bulkhead)



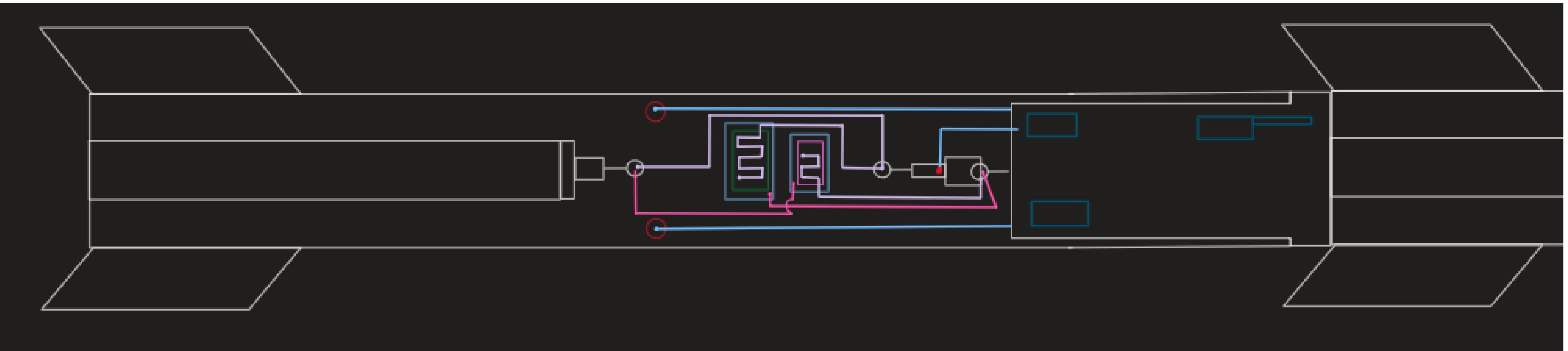
- The wiring will feed from three quick connects to six terminal blocks. To allow remove of the bulkhead.
- There are six E-matches wired from the terminal blocks, to three black powder charges.
- The additional E-matches per black powder charge allow for redundancy.
- The apogee event features two charges for additional redundancy, to further ensure proper coupler ejection.
- Apogee and Main wires will remain uncharged until specific flight parameters are met.

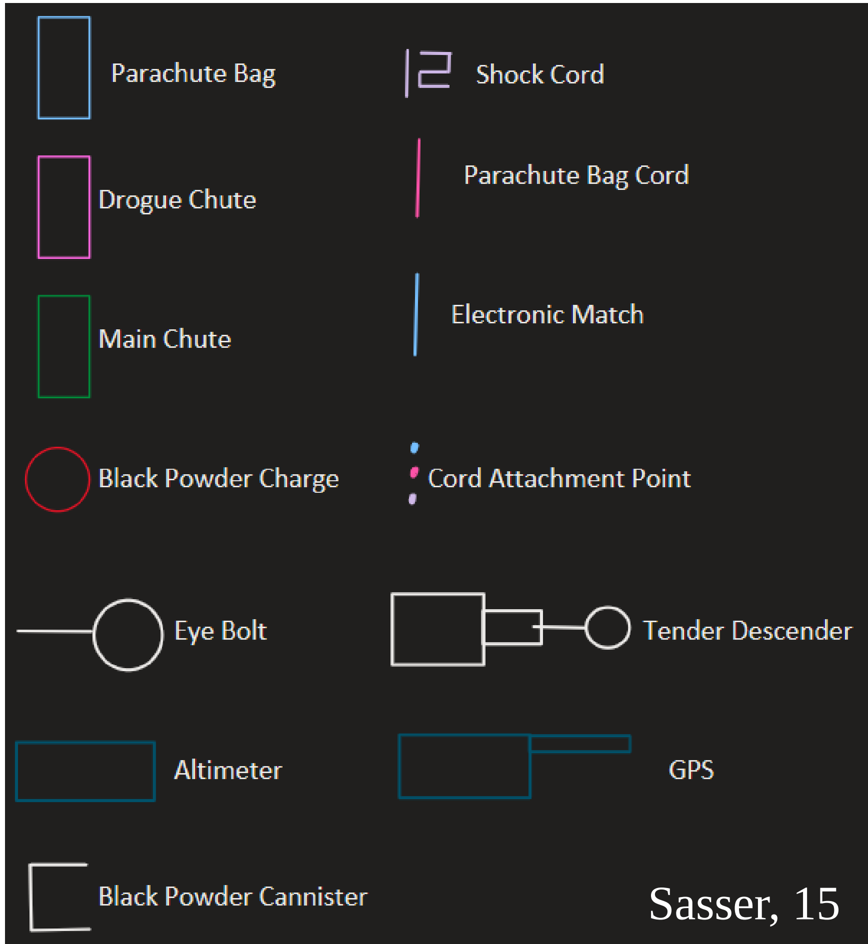
Black Powder Charge

Terminal Block

Booster Recovery Diagram

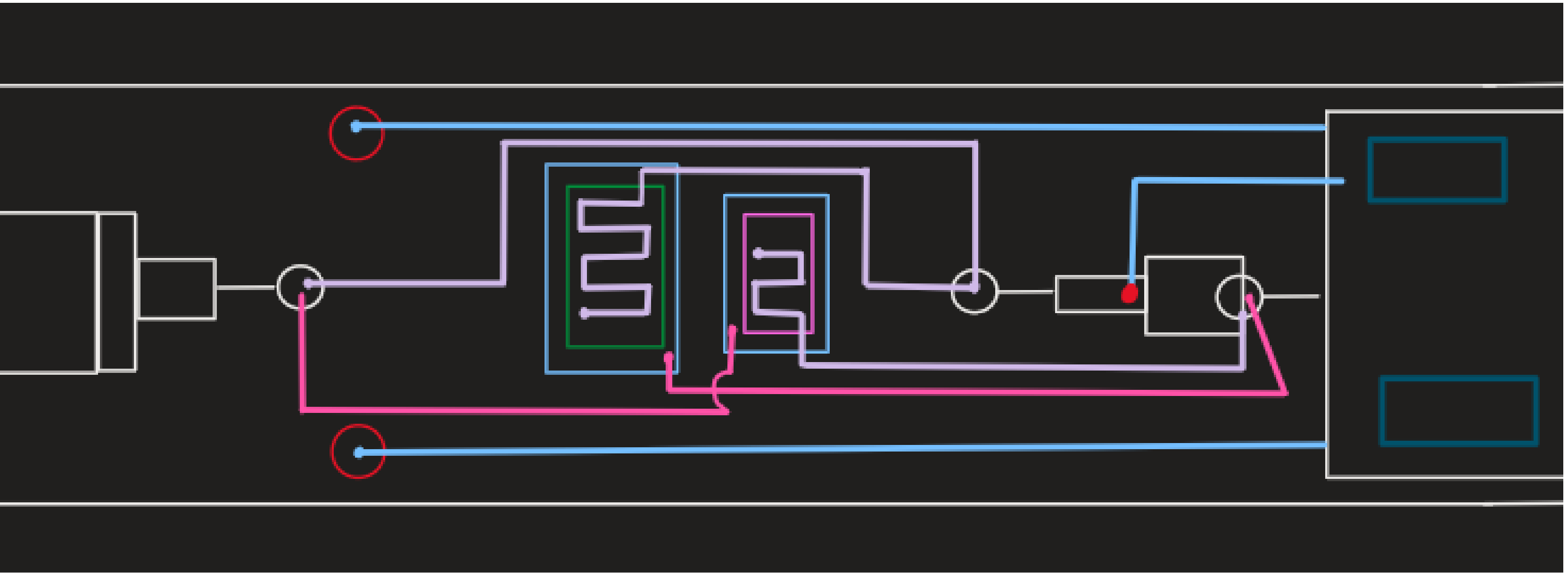
- There are three major flight stages
- **Stage 1: Before Apogee**, how the system will be initially constructed.
- **Stage 2: Apogee**, when the coupler is ejected and drogue chute deployed.
- **Stage 3: 1000 feet**, when the main chute is deployed.

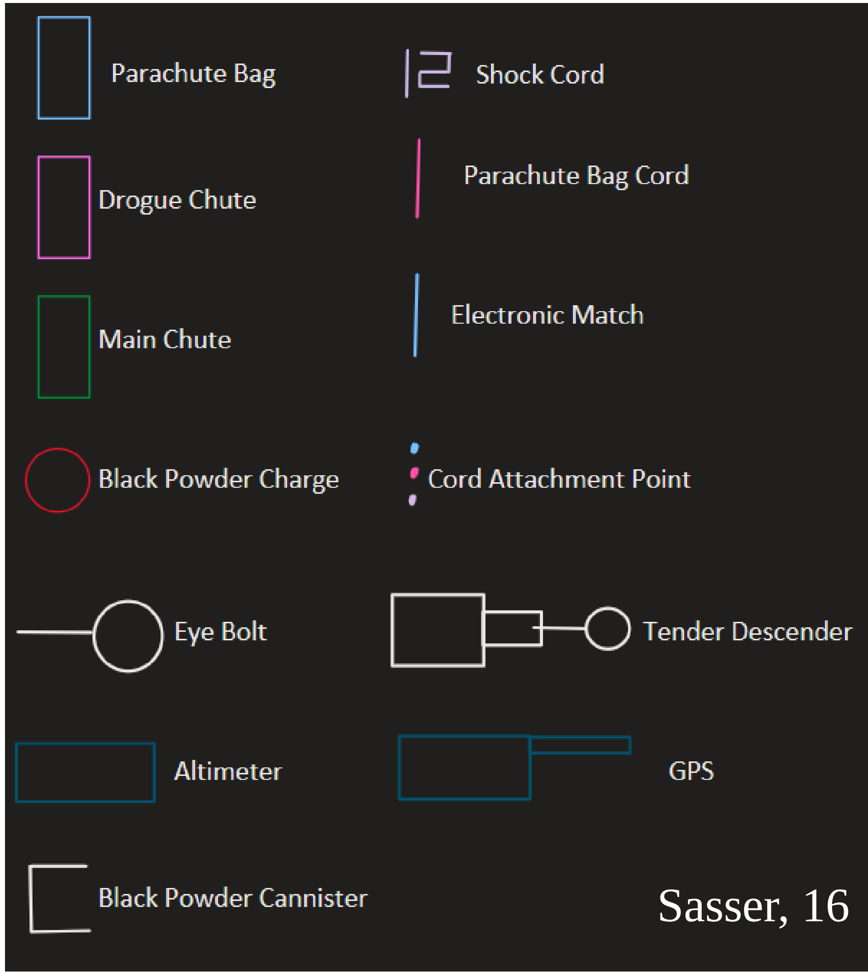




Booster Recovery Diagram Stage 1

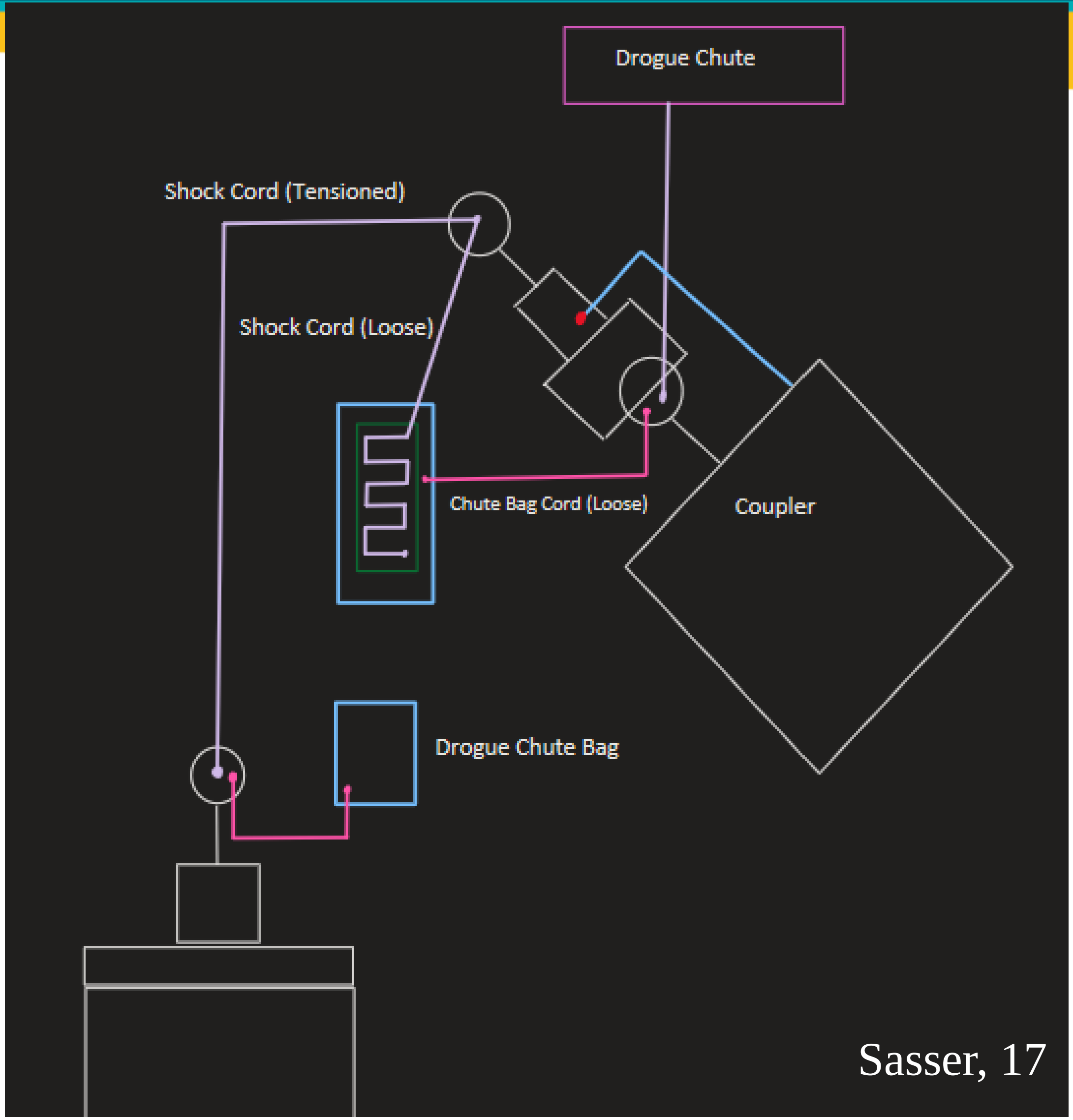
- The black powder charges will be placed in the aft end of the booster stage, to allow the coupler and parachutes to be ejected.
- The shock cords have specific lengths and connection points to ensure the parachutes release at the correct staging





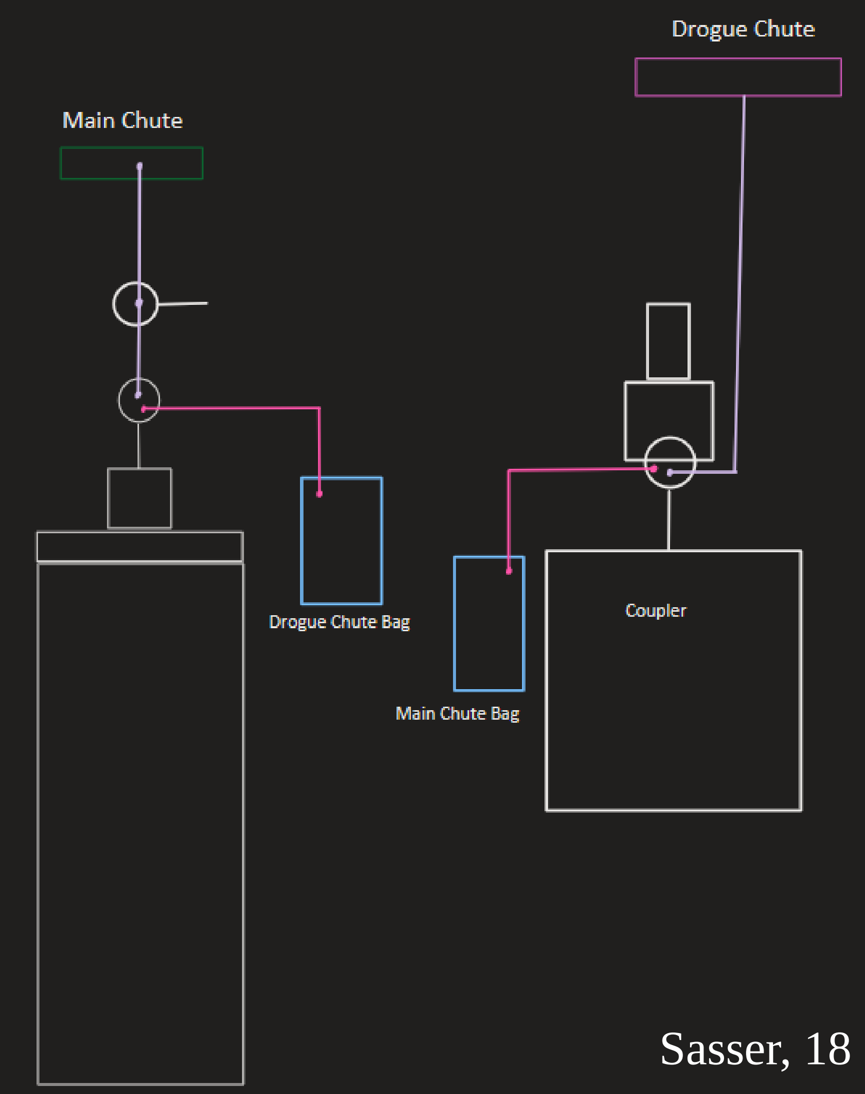
Booster Recovery Diagram Stage 2

- At apogee, the black powder charges will ignite and eject the couplers and both parachutes.
- The drogue chute will be pulled out of its bag by the impulse.
- The main parachute will remain in its bag and be hanging from the tender descender eye bolt.
- At stage 3, a black powder charge will cause the tender descender forward eye bolt to be ejected.



Booster Recovery Diagram Stage 3

- With the forward eye bolt ejected, the booster stage begins to free fall, while the coupler is descending with the drogue chute.
- From this, the main chute will be pulled out of its bag and allow for the main chute to be deployed.
- After that, the booster stage falls separate from the coupler.



Descent Rate Simulation

Parachute Specifics	Booster Drogue	Booster Main	Sustainer Drogue	Sustainer Main
Diameter (ft)	5	12	6	12
CD	2.2	2.2	2.2	2.2
Descent Rate (ft/s)	34.7	14.4	28.9	14.4
Price ($)	150	385	170	385

- Sustainer Stage Weight is 56.2 lbs. (No Fuel).
- Booster Stage Weight is 36 lbs. (No Fuel).

- All Descent rates tested with sustainer stage at 51.7 lbs. It is done this way since RASAero only tests the sustainer stage.

- The booster descent rates will be significantly lower.

Black Powder Analysis

- It starts with measurements of the inner diameter and length of the rocket's pressurized section to calculate its volume.
- An empirical constant is used to estimate the amount of black powder required to produce the desired pressure.
- A 25% safety margin is added to ensure the charge is effective even with minor losses or variations.
- The final recommended black powder charge is approximately 2.4 grams for reliable nose cone separation.

Hot Separation

- A hot separation for the rocket, using the AeroTech N3300 motor with a 4.18-second booster burn, involves the sustainer motor igniting to force booster stage disconnection while ensuring safety and optimizing apogee.
  - **Booster Burn Timing**: AeroTech N3300 burns for 4.18s; sustainer ignites post booster burn out.
  - **Altimeter Control**: Altimeters use timing, velocity decreasing, and optional delay to trigger sustainer ignition.
  - **Time Delay Option**: Brief delay after burnout boosts apogee but lowers velocity, needing precise tuning.

Magnetic Separation Design Process

- Previous design included
  - Springs
  - 2 sets of 6 magnets
- Reworking past design
  - Budget
  - Material
- Constraints
  - Inner tube diameter
  - Outer ring with teeth surface area

Manufactured Booster Mag Sep

Manufactured Sustainer Mag Sep

Magnetic Separation

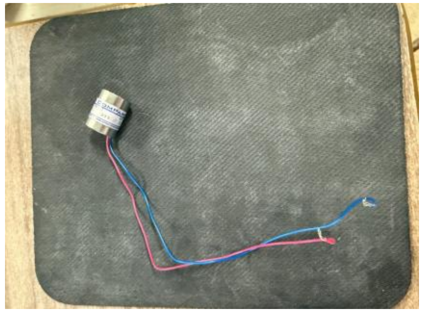
Stages will be connected by rings with teeth and a cylinder that slides up from the booster into the sustainer

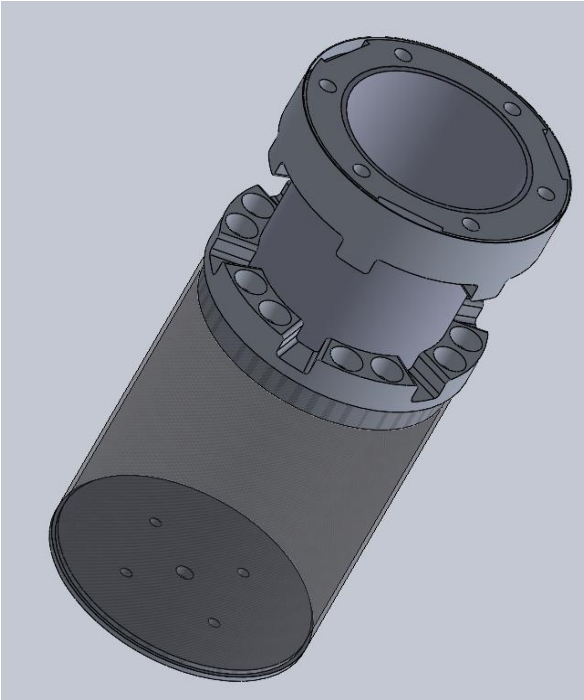
2 magnets will be in each “large tooth” for a total of 12 magnets per ring

Electromagnets will be used with a rating of 10 pound-force each

Magnets will be secured into each hole using epoxy or threaded rods
- Research is being conducted to possibly thread the magnets into the rings

Wind tunnel testing will be conducted to analyze drag differentials
- Courtesy of Embry-Riddle

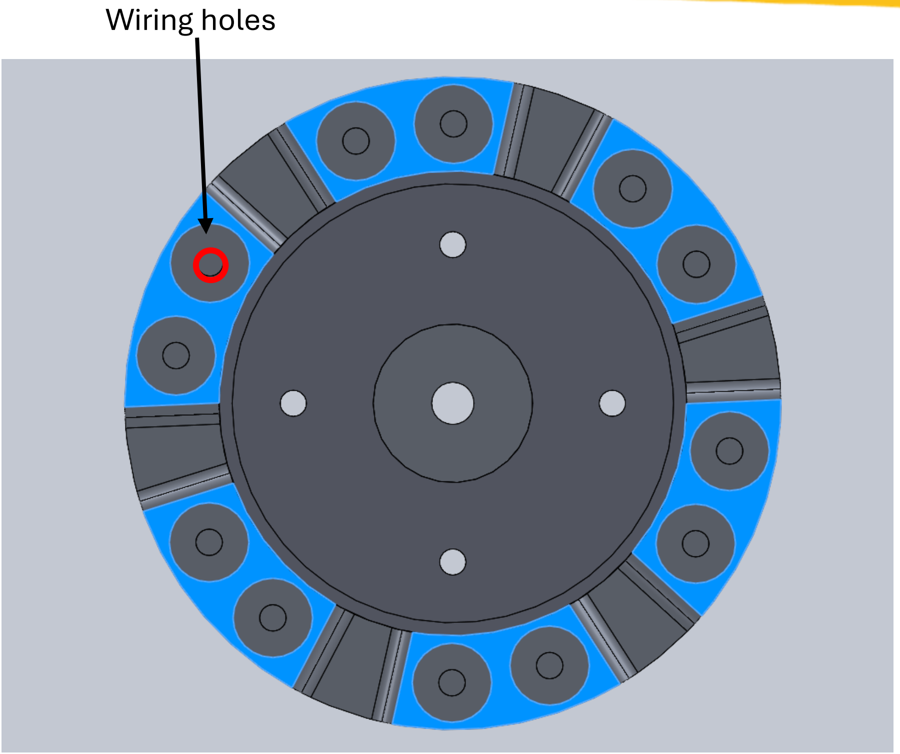


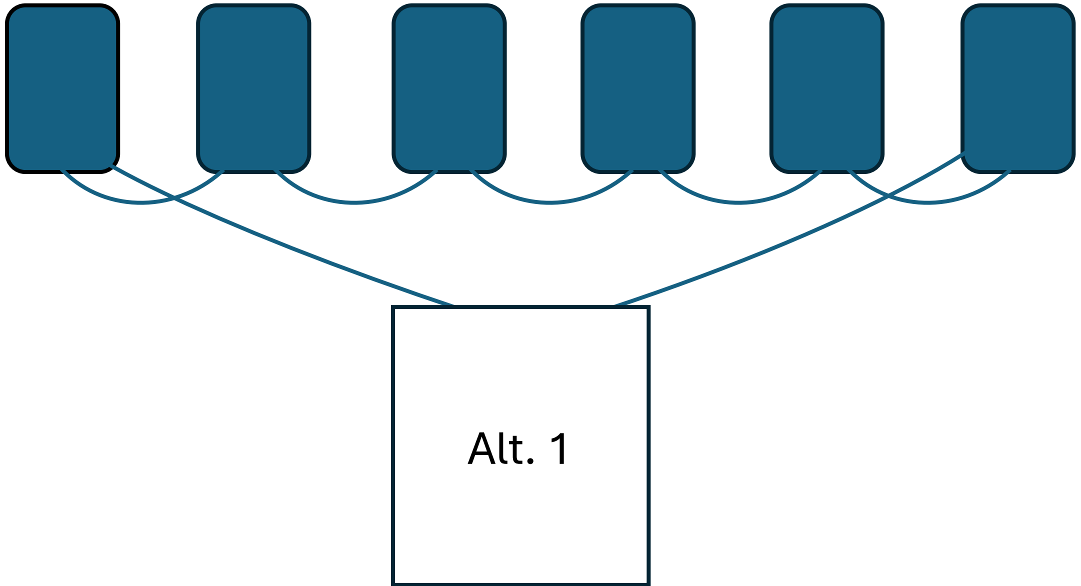


Magnetic Separation

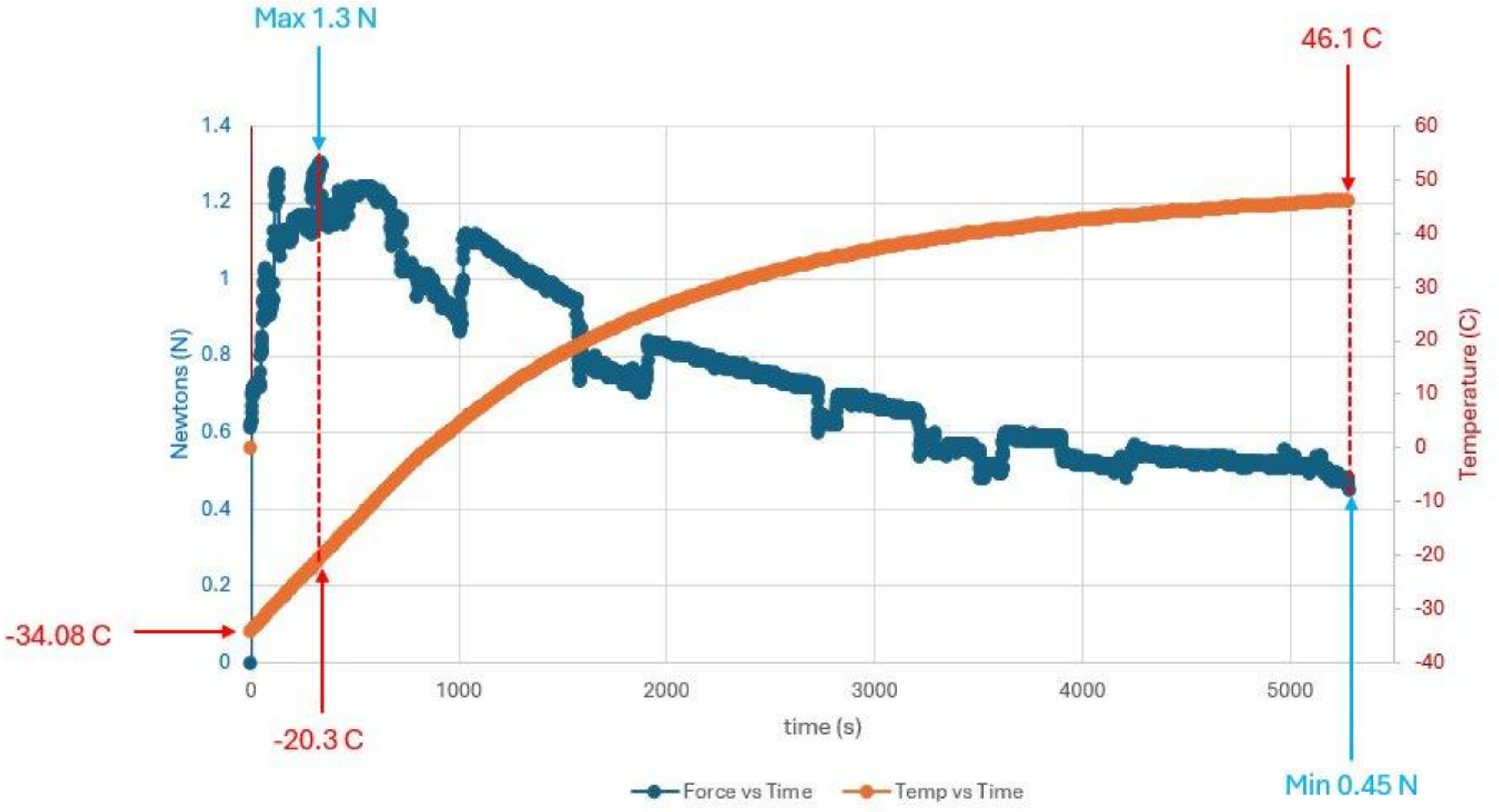
- Magnets will be wired through the aluminum rings with teeth

- Originally were going with 12 electromagnets on each ring
  - Victoria suggested earlier this week to possibly use permanent magnets on one ring
  - The team will further research this idea



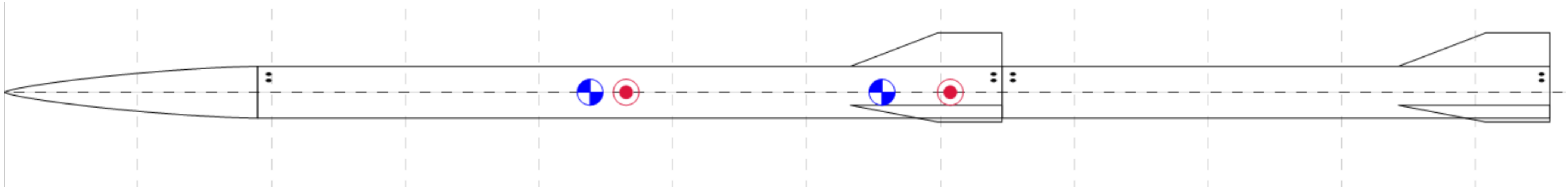


Magnet Thermal Effects

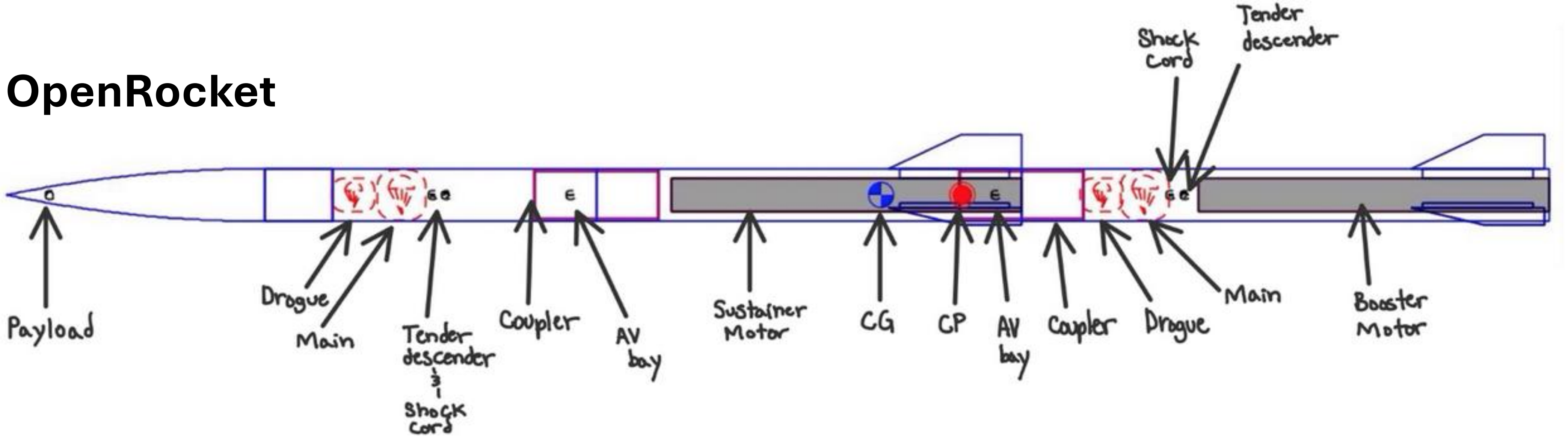


Flight Simulation Tools

RASAero II



OpenRocket



Flight Simulation Tools

	RASAero II	OpenRocket
Velocity:	1,759.9 [ft/s]	2,003 [ft/s]
Apogee:	22,937 [ft]	33,195 [ft]
Drag Force:	Booster & Sustainer before separation: 112.98 [lbf] Sustainer after separation: 336.52 [lbf]	Booster & Sustainer before separation: 94.13 [lbf] Booster after separation: 182.91 [lbf] Sustainer after separation: 224.2 [lbf]
Mach #:	1.56	1.824

Flight Simulation Tools (Suspected Differences)

OpenRocket

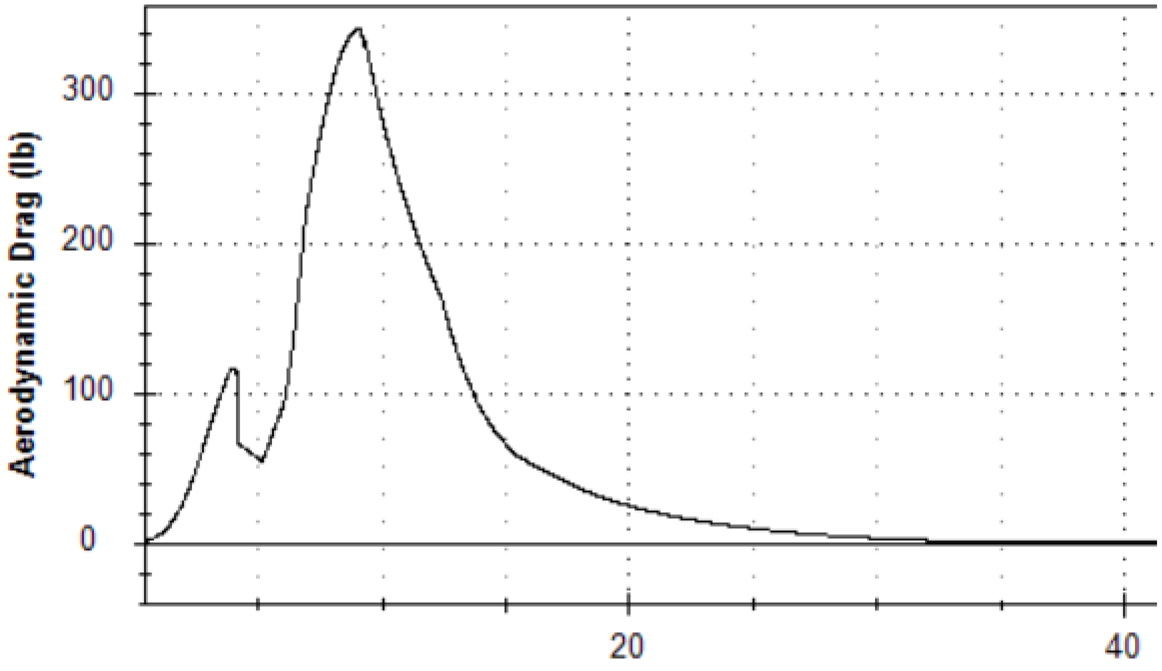
- Less accurate for transonic (Mach 0.8–1.2) and supersonic (Mach > 1) regimes.
- Uses simplified models (Barrowman or RockSim-like), which tends to underestimate drag.

RASAero II

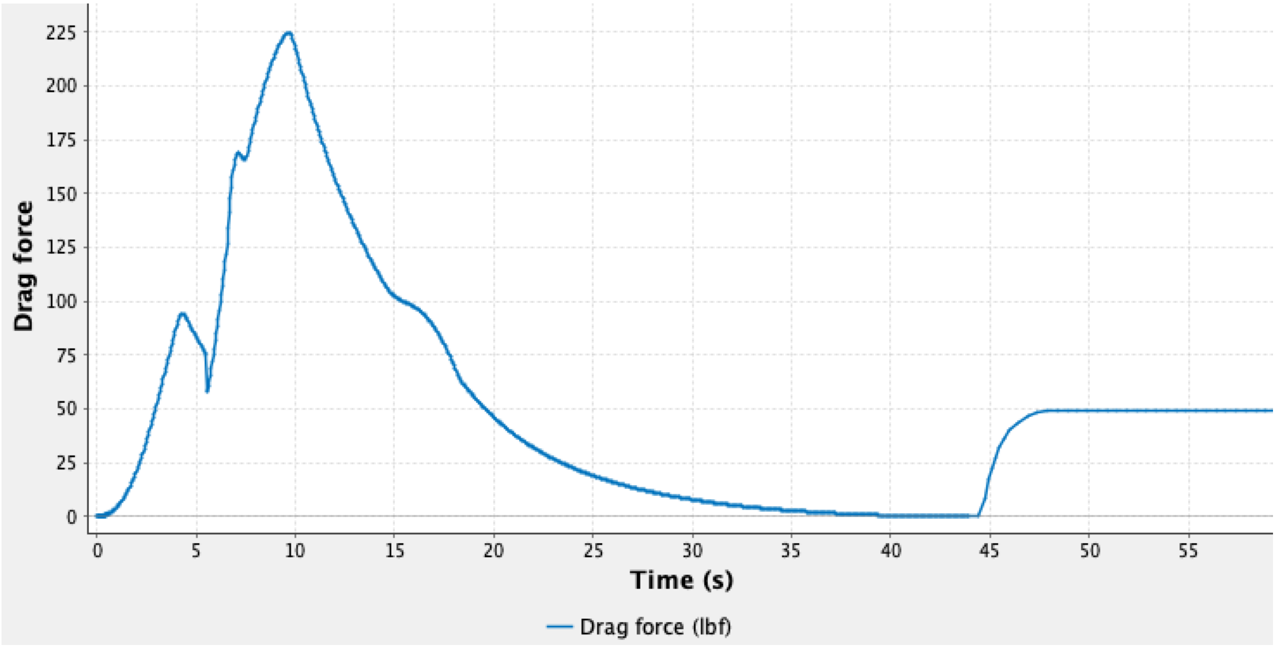
- More accurate for transonic and supersonic flights (Mach > 0.8) & high-altitude rockets
- Uses empirically derived Cd tables based on wind tunnel data and flight tests.

Drag Simulation Data Comparison

RASAero II



OpenRocket



BOM

Line Number	Item	Description	Quantity	Unit Cost	Total Cost	Need Date	Date	Date Ordered	Date Received	Grand Total	$5,732.03
	MAGSEP										
	Magnets	40 lbf	2	$10.00	$20.00	11/15/2025	9/6/2025	2/10/2025	2/24/2025		EXAMPLE
1	Electromagnets	10 lbf	12			10/1/2025	5/10/2025				
2	Materials	Aluminum	TBD	TBD	TBD	11/15/2025	9/6/2025				
3	Manufacturing	No cost courtesy of NOVA Kinetics	N/A	$0.00	$0.00	11/15/2025	9/6/2025	4/1/2025	4/18/2025		
4	12V Battery	Powers electromagnets	1			10/1/2025	5/10/2025				
5	Insulation	Insulates magnetic strength	TBD			10/1/2025	9/10/2025				
6	Arduino	No cost courtesy of Bob	1	N/A	$0.00	4/11/2025	N/A	N/A	N/A		
7	Load cell / strain gauge	Magnetic experiment	1	$53.88	$53.88	4/11/2025	4/8/2025	4/8/2025	4/13/2025		Used GoFundMe funds
	MISCELLANEOUS										
8	Booster	N2220 —>N3300R upgrade	1	$200.00	$200.00	Sep-25	Apr-25	24-Apr	N/A		
9	Fiber Glass	No cost courtesy of NOVA Kinetics	TBD	$0.00	$0.00	Aug-25	N/A	N/A	N/A		
	RECOVERY										
10	Parachute	CD 2.2 Parachute (Sustainer Drogue)	1	$170.00	$170.00	Sep-25	Apr-25	4/17/2025			
11	Parachute	192-in Main Chute CD 2.2 (1 for booster 1 for sustainer)	2	$620.00	$1,240.00	Sep-25	Apr-25	4/17/2025			
12	Parachute	60-in Rocketman High Performance CD 2.2 Parachute (Booster Drogue)	1	$150.00	$150.00	Sep-25	Apr-25	4/17/2025			
13	Tender descender	L3 rated for 300 [lb] rockets for booster stage	1	$145.00	$145.00	Sep-25	Apr-25	4/17/2025			
14	50 [ft] 8,600-lb shock cord	2 cords per stage	4	$270.00	$540.00	Sep-25	4/25/2025				
15	Custom parachute bags	1 bag for each Parachute	4			Sep-25	Apr-25				
	2ND LAUNCH										
16	Propellant reload kit	N3300R reload kit for booster & sustainer	2	$1,154.00	$2,308.00	Nov-25	Sep-25				
	ELECTRONICS										
17	Featherweight GPS tracking system		1	$529.27	$529.27	Sep-25	Mar-25	3/19/2025	3/28/2025		
18	Featherweight blue raven altimeters (2-in-1 kit)		1	$330.00	$330.00	Sep-25	Mar-25	3/28/2025	3/31/2025		
19	Key switch	For turning on avionics	2	$10.00	$20.00	Sep-25	Apr-25				
20	PCB board	Increase number of outputs	2			Sep-25	Apr-25				
21	Wires	Wiring for avionics, magsep, etc. (donated by NAU EE Lab)	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
22	Quick Links (rated for 2200 [lbs])	Shock cord attatchments	4	$6.47	$25.88	Sep-25	Apr-25				
										Theoretical Balance	$1,017.10

Total funding for the team is $6,115.13

- $5,000 initial budget
- $1,115.13 left over from previous semester

The team has fundraised approximately $800

- ~$700 from GoFundMe
- ~$100 from PandaExpress
- Material donations

Nationwide PandaExpress fundraiser on May 23rd!

Future Testing

- **Recovery System Testing**
  - Ensure black powder charges eject couplers and recovery systems.
- **MAG-SEP Testing**
  - Characterizing magnetic force.
  - Proper separation of booster and sustainer stages.
- **Wind Tunnel Testing (Drag)**
  - Characterizing drag coefficients of each stage
  - Assists in MAG-SEP force required.
- **Data Collection in September Launch**
- **Tube Compression Testing**
  - Determine maximum force body tubes can endure

Future Work

- Finish Aft and Forward motor retainers
- Design igniting system for motors
- Launch Materials Check List, Launch Procedure, Safety Procedure
- Altimeter Safety Programming (If rocket tilts over, sustainer motor will not ignite)
- Talk to Blue Origin Guy about BP charges for high altitudes
- MAG-SEP Fabrication
- Modifying or repairing any damages from September Launch

Conclusion

In conclusion, the project has made significant progress in designing and testing the rocket's recovery systems, magnetic separation mechanisms, and avionics, with valuable contributions from the team and advisors. The team's efforts, supported by thorough analysis and simulations, have laid a solid foundation for hopefully successful launches.

Recognition

On behalf of the team, we would like to thank the following individuals for their contributions to the project.

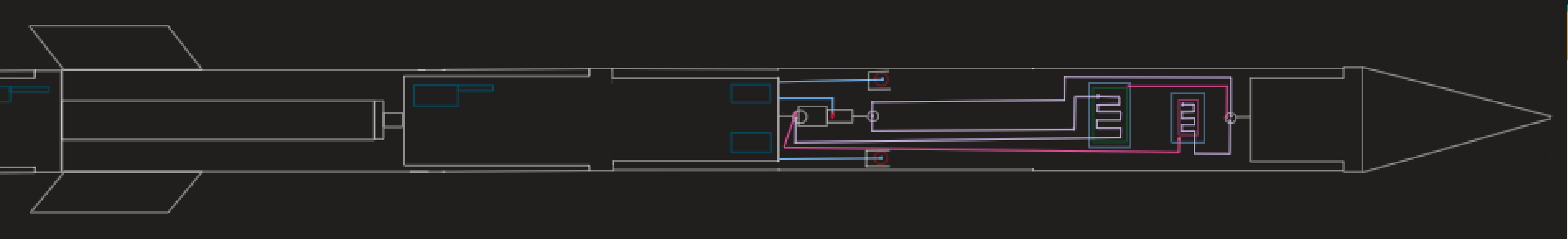
- **Northrop Grumman**
- **Caleb Feda**
- **Victoria Ewert**
- **Jessica Westerham**
- **Carson Pete**
- **Rick Maschek (L3 advisor)**
- **Aminul Khan (Faculty Advisor)**

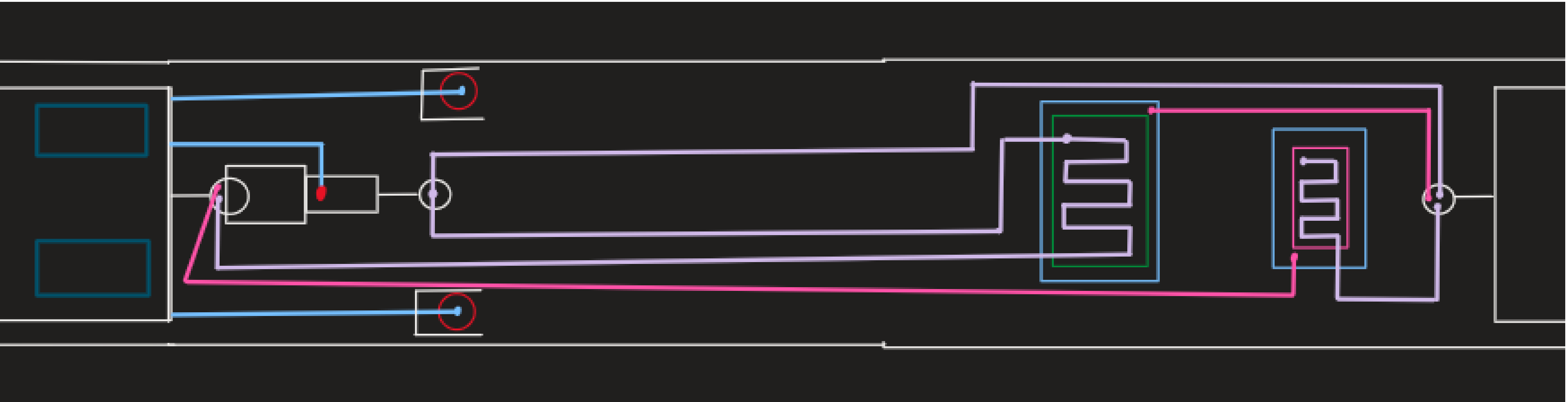
Thank You

Any Questions?

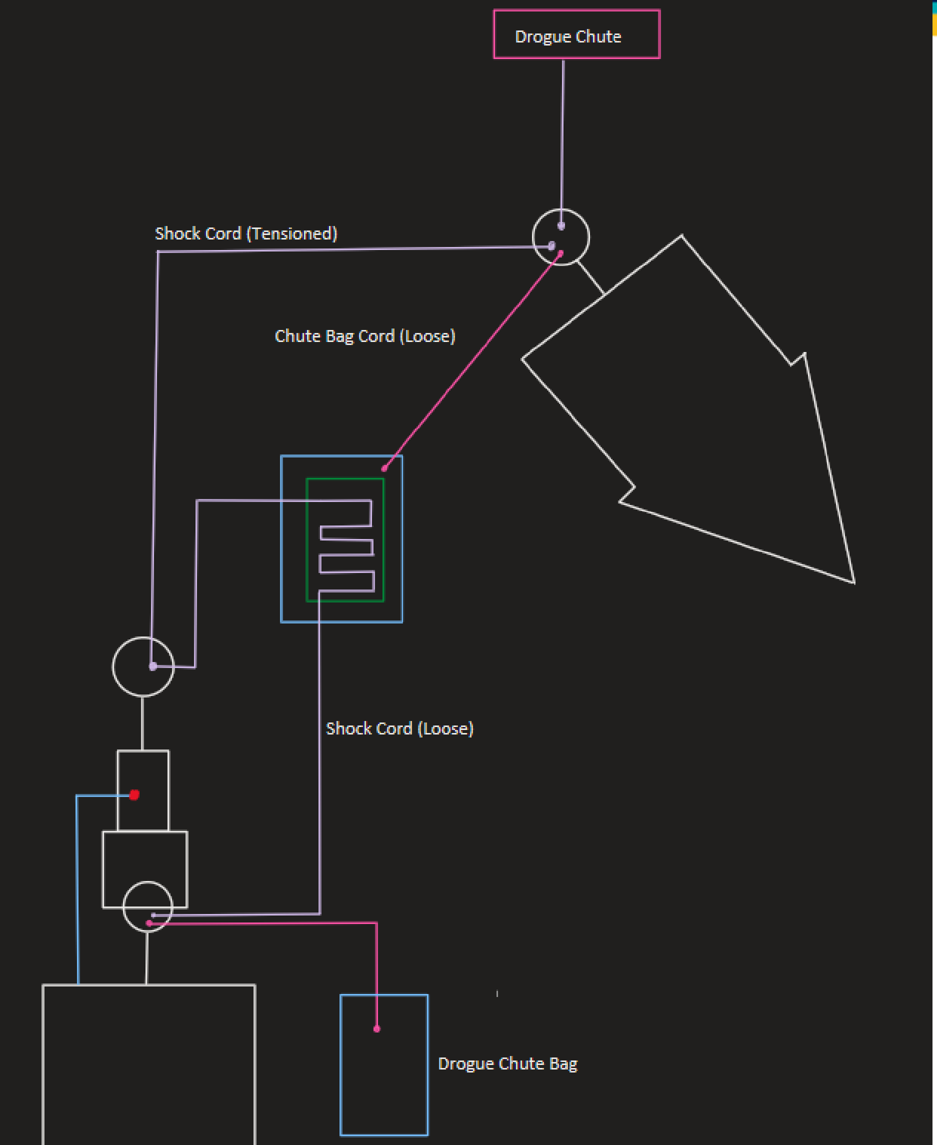
Appendix

A1 – Sustainer Recovery Diagram Stage 1

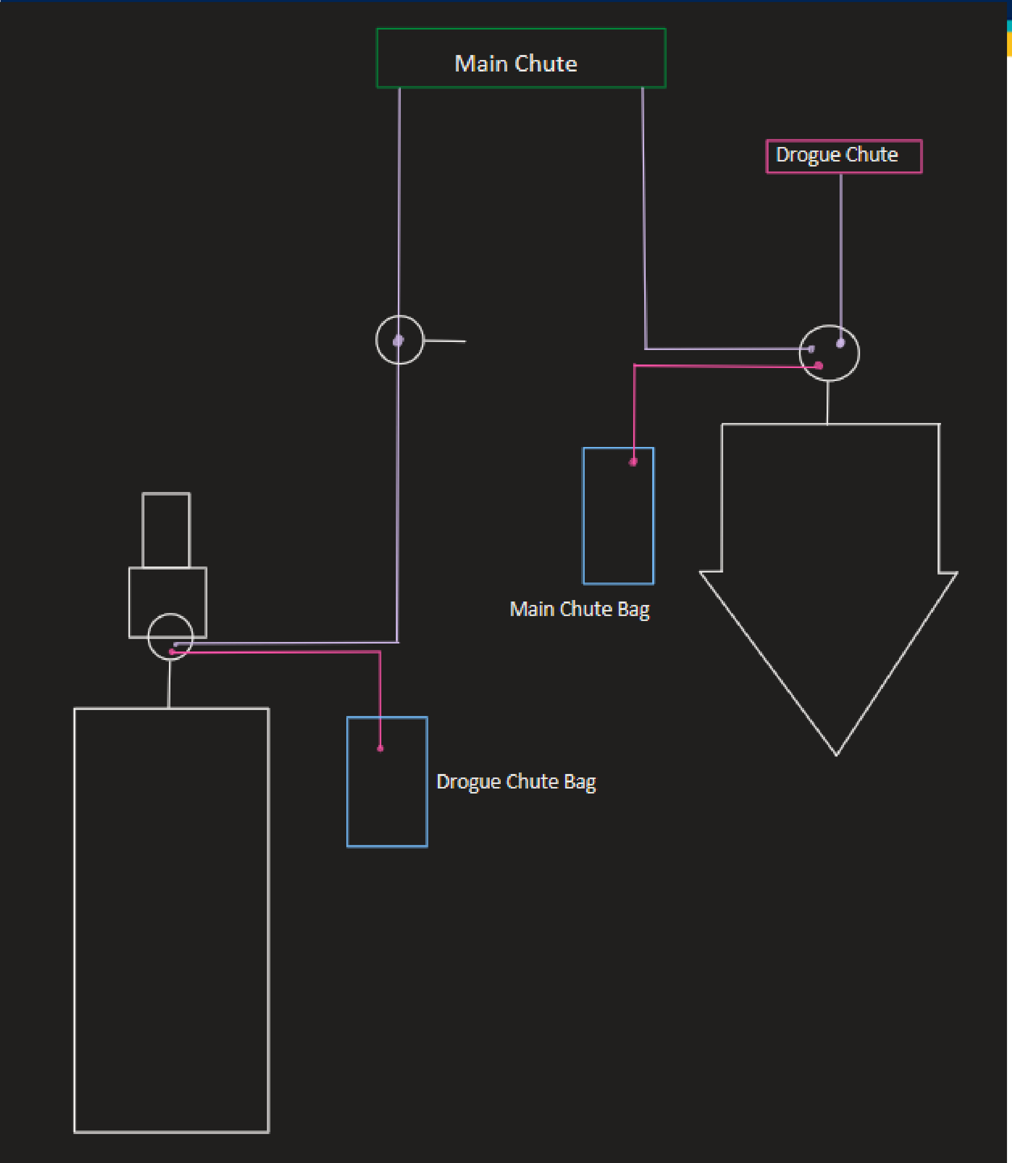




A2 – Sustainer Recovery Diagram Stage 2



A3 – Sustainer Recovery Diagram Stage 3



A4-Black Powder Analysis Code

```
%Lee Freytes Colon
%Black Powder Charge Calculation (4/18/2025)

% Input parameters
inner_diameter = 6.0; % Inner diameter of Sustainer Tube 1 (inches), assumed based on nose cone coupler OD
pressurized_length = 10.0; % Length of pressurized section in Sustainer Tube 1 (inches), assumed
desired_pressure = 100; % Desired pressure for separation (psi)
empirical_constant = 15000; % Empirical constant for black powder (in³·psi/g)
safety_margin = 1.25; % Safety margin multiplier (25% extra powder)

% Calculate pressurized volume
radius = inner_diameter / 2; % Radius of Sustainer Tube 1 (inches)
volume = pi * radius^2 * pressurized_length; % Volume in cubic inches

% Calculate black powder mass using empirical formula: m = (V * P) / C
mass = (volume * desired_pressure) / empirical_constant; % Mass in grams

% Apply safety margin
mass_adjusted = mass * safety_margin; % Adjusted mass with safety margin

% Output results
fprintf('Black Powder Charge Calculation for Nose Cone Separation\n');
fprintf('Inner Diameter of Sustainer Tube 1: %.2f inches\n', inner_diameter);
fprintf('Pressurized Section Length: %.2f inches\n', pressurized_length);
fprintf('Pressurized Volume: %.2f cubic inches\n', volume);
fprintf('Desired Pressure: %.2f psi\n', desired_pressure);
fprintf('Calculated Black Powder Mass: %.2f grams\n', mass);
fprintf('Adjusted Black Powder Mass (with %.0f%% safety margin): %.2f grams\n', (safety_margin-1)*100, mass_adjusted);
fprintf('Rounded up the Black Powder Mass needed is around 2.4 grams')
```

```
Black Powder Charge Calculation for Nose Cone Separation
Inner Diameter of Sustainer Tube 1: 6.00 inches
Pressurized Section Length: 10.00 inches
Pressurized Volume: 282.74 cubic inches
Desired Pressure: 100.00 psi
Calculated Black Powder Mass: 1.88 grams
Adjusted Black Powder Mass (with 25% safety margin): 2.36 grams
Rounded up the Black Powder Mass needed is around 2.4 grams
```

A5 – Fundraiser Flyer

FUNDRAISER FOR

NRG Supersonic Rocket Capstone Team

When
Friday, May 23, 2025
Place your order for pickup or delivery on Friday, May 23!

Where
Available at Panda Express locations nationwide
www.pandaexpress.com

How
Online orders only
Apply code **9003804** in the Fundraiser Code box during online checkout at www.pandaexpress.com or via App

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28% of sales will be donated to: NRG Supersonic Rocket Capstone Team

Building a rocket, chasing dreams, and pushing limits,every donation fuels our journey to success.

Valid for online orders only. Panda Restaurant Group, Inc. ("PRG") reserves the right to cancel any and all fundraiser events at any time, if the Virtual Community Fundraising Terms and Conditions are not followed. If the organization is not in good standing with the IRS, Franchise Tax Board, or the State of California (for California organizations only), then donations may not be made to the organization. The organization must raise a minimum of $150 in total event sales pre-tax, at your local Panda Express when purchased with designated code at check-out, in order to receive 28% of all event sales (pre-tax amount). PRG does not charge the organization fees related to the event. Purchase(s) of gift cards and meals from Panda's School Lunch program do not count towards the fundraiser, but purchases made with gift cards will count. No portion of purchase is tax deductible. The donation from PRG to the organization is tax deductible. The organization receiving the donation must be a tax exempt organization. PRG will issue the donation check and provide an accounting statement to the organization within 45 days of the completion of the Event. Participants in the fundraiser may request the total dollar amount donated to the organization by emailing communityprograms@pandarg.com or by submitting the question at https://community.pandaexpress.com/faq.